Project Report: Genomic Record of the Earth's Early Biosphere

Project Investigator:	**_S. Blair Hedges_**

Project Progress

Our research involves molecular clocks and phylogenetics to better understand the relationship between planetary history and the evolution of life. We made progress in theoretical and empirical studies during the past year. In the former area we developed a robust method for estimation of the mode, and tested it with computer simulations (Hedges and Shah, 2003). Such a method is useful for any data, but our immediate use was with molecular clock analyses. We also developed a method for phylogenetic analysis of complete genome sequences (Blair and Hedges, ms). In another paper, I developed a biological trigger model for snowball Earth events (Hedges, 2003).

Our empirical work involved eukaryote and prokaryote studies. We sampled all available protein sequences in the public databases (20–200 genes per node) to develop a tree and timescale of eukaryotes. With that framework we showed that complexity (as measured by cell types) has increased much earlier than previously believed (Hedges et al., 2004). In another study using similar methods we determined time estimates for the colonization of land by metazoans in the late Precambrian (Pisani et al., 2004). Our prokaryote genome work resulted in a detection of early horizontal gene transfer events (Thomarat and Hedges, ms), a more robust timescale for prokaryote evolution, and better constraints on the origin of organisms producing metabolic products that influenced the history of the biosphere (Battistuzzi and Hedges, ms).

Highlights

- Biological trigger for snowball Earths (Hedges, 2003): Although it is commonly assumed that snowball Earths were triggered by a geologic event, the unusual equatorial alignment of continents, we propose instead that they were triggered by a biological event: the colonization of land by fungi and plants. This biological trigger model also may explain the cyclic nature of snowball Earth events and the Cambrian Explosion of animals.
- Early rise in complex life (Hedges et al., 2004): Our molecular clock studies of large numbers of genes revealed that complex multicellular life appeared about a billion years earlier than indicated by the fossil

record.

Roadmap Objectives

- ***Objective No. 4.1:*** Earth's early biosphere
- ***Objective No. 4.2:*** Foundations of complex life
- ***Objective No. 4.3:*** Effects of extraterrestrial events upon the biosphere

Mission Involvement

Mission Class*	***Mission Name (for class 1 or 2) OR Concept (for class 3)***	***Type of Involvement*****
2	TPF	Background Research
3	Mars and Europa	Background Research

* Mission Class: Select 1 of 3 Mission Class types below to classify your project:
1. Now flying OR Funded & in development (e.g., Mars Odyssey, MER 2003, Kepler)
2. Named mission under study / in development, but not yet funded (e.g., TPF, Mars Lander 2009)
3. Long–lead future mission / societal issues (e.g., far–future Mars or Europa, biomarkers, life definition)

** Type of Involvement = Role / Relationship with Mission
Specify one (or more) of the following: PI, Co–I, Science Team member, planning support, data analysis, background research, instrument/payload development, research or analysis techniques, other (specify).

Our research on the early evolution of life on Earth provides background information for any future NASA missions searching for life elsewhere. Our evolutionary timescales help constrain the development and evolution of a planetary biosphere and therefore provide and enhance the general biomarkers for life.

Cross Team Collaborations

The PI (Hedges) is the co–Chair of a cross–team focus group: Evolutionary Genomics Focus Group. This focus group held a workshop at the Gordon Research COnference meeting on Origin of Life in Maine during July, 2003.